EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management

The EUMETSAT Network of Satellite Application Facilities

H SAF
Support to Operational Hydrology and Water Management

Product User Manual (PUM)
for product H08 – SM-OBS-2

SM-OBS-2 - Small-scale surface soil moisture by radar scatterometer

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1.0	20/01/2012	Baseline version prepared for ORR1 Part 3.
1.1	05/07/2012	Updated version.
1.2	30/11/2014	Specification of sampling distance/resolution, added BUFR decoding example.
1.3	09/02/2015	Updated chapter “Versioning history”.
1.4	02/03/2015	Section 4 (“Product Availability”) and Annex 3 (“Introduction to H-SAF”) updated.

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1 Introduction

1.1 Purpose of the document

Product User Manuals are available for each (pre)-operational H-SAF product, for open users, and also for demonstrational products, as necessary for *beta-users*.

Each PUM contains:

- Product introduction: principle of sensing, Satellites utilized, Instrument(s) description, Highlights of the algorithm, Architecture of the products generation chain, Product coverage and appearance;
- Main product operational characteristics: Horizontal resolution and sampling, Observing cycle and time sampling, Timeliness;
- Overview of the product validation activity: Validation strategy, Global statistics, Product characterisation;
- Basic information on product availability: Access modes, Description of the code, Description of the file structure.

An annex also provides common information on Objectives and products, Evolution of H-SAF products, User service and Guide to the Products User Manual.

Although reasonably self-standing, the PUMs rely on other documents for further details. Specifically:

- ATDD (*Algorithms Theoretical Definition Document*), for extensive details on the algorithms, only highlighted here;
- PVR (*Product Validation Report*), for full recount of the validation activity, both the evolution and the latest results.

These documents are structured as this PUM, i.e. one document for each product. They can be retrieved from the CNMCA site on HSAF web page at User Documents session.

1.2 Introduction to product SM-OBS-2

1.2.1 Principle of sensing

Product SM-OBS-2 (Small-scale surface soil moisture by radar scatterometer) results from post-processing of the SM-OBS-1 product extracted by ZAMG from the Global surface soil moisture product distributed by EUMETSAT. Product SM-OBS-1 is based on the radar scatterometer ASCAT embarked on MetOp satellites. The instrument scans the scene in a push-broom mode by six side-looking antennas, three left-hand, three right-hand (see Fig. 06). On each side, the three antennas, looking aside, + 45° and - 45° respectively, provide three views of each earth location under different viewing angles measuring three backscattering coefficients (σ0, sigma-nought) at slightly different time. Each antenna triplet provides a side swath of 550 km. The two swaths leave a gap (close to the sub-satellite track) of ~ 670 km. Global coverage over Europe is achieved in ~ 1.5 days.

The basic instrument sampling distance is 12.5 km. The primary ASCAT observation, sea-surface wind, is processed at 50 km resolution. For soil moisture, processing is performed at 50 km (operational) and 25 km (research) resolution with a sampling distance of 25 km and 12.5 km, respectively.

For the purpose of SM-OBS-2, the 25-km resolution (12.5 km sampling distance) SM-OBS-1 product is disaggregated and re-sampled at 1-km intervals to better fit hydrological requirements.

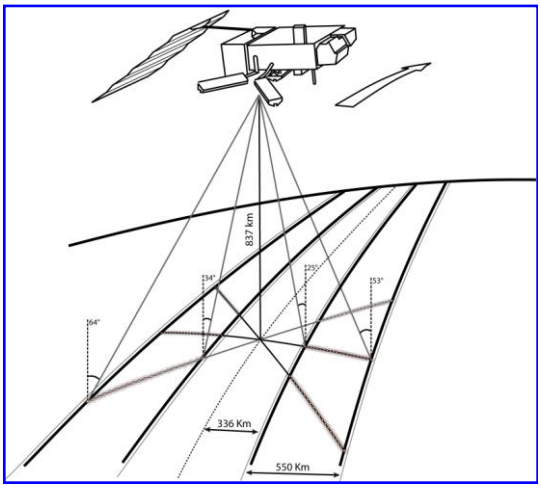

Figure 1 – Scanning geometry of ASCAT

The disaggregation process (see Fig. below) makes use of a fine-mesh layer pre-computed and stored in a parameter database. The fine-mesh information includes backscatter and scaling characteristics derived from SAR imagery from Envisat ASAR operating in the ScanSAR Global monitoring mode.

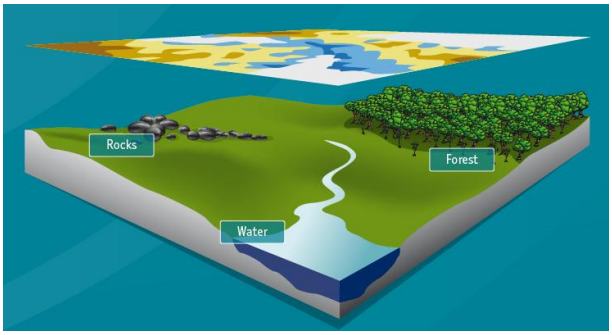

Figure 2 – Principle of disaggregation by auxiliary data

1.2.2 Status of satellites and instruments

The current status of MetOp and Envisat satellites is shown in ***Table 01***.

Satellite	Launch	End of service	Height	LST	Status	Instruments used in H-SAF
MetOp-A	19 Oct 2006	expected ≥ 2012	817 km	09:30 d	Operational	ASCAT
Envisat	1 Mar 2002	09 May 2012	800 km	10:00 d	Terminated	ASAR

Table 1 Current status of MetOp and Envisat satellites (as of March 2010)

Although ASCAT data are not directly used (the processed SM-OBS-1 product is used instead), its main characteristics, that are reflected in SM-OBS-2, are recorded in the ***Table 02***. The main features of ASAR, that is used for building the database of disaggregation parameters, are recorded in ***Table 03***. Envisat was managed by ESA, and ASAR data are available from the ESA archives. The statistical parameters for the later downscaling process are derived from a multi-annual image-analysis of ASAR C-band data (several hundreds of images per pixel) and stored in a parameter database, which needs to be updated only rarely. The SAR imagery used for generating the database is ENVISAT ASAR in ScanSAR Global Mode (years 2004-2012) and, planned for future, imagery from the upcoming Sentinel-1 satellite.

ASCAT	Advanced Scatterometer
Satellites	**MetOp-A, MetOp-B, MetOp-C**
Status	**Operational** - Utilised in the period: 2006 to ~ 2021
Mission	Sea surface wind vector. Also large-scale soil moisture
Instrument type	Radar scatterometer - C-band (5.255 GHz), side looking both left and right. 3 antennas on each side
Scanning technique	Two 550-km swaths separated by a 700-km gap along-track. 3 looks each pixel (45, 90 and 135° azimuth)
Coverage/cycle	Global coverage in 1.5 days
Resolution	Best quality: 50 km – standard quality: 25 km – basic sampling: 12.5 km
Resources	Mass: 260 kg - Power: 215 W - Data rate: 42 kbps

Table 2 Main features of ASCAT

ASAR	Advanced Synthetic Aperture Radar - SAR mode
Satellite	**Envisat**
Status	**Terminated -** Utilised in the period 2002 to 09 May 2012
Mission	High-resolution all-weather multi-purpose imager for ocean, land and ice
Instrument type	Imaging radar - C-band SAR, frequency 5.331 GHz, multi-polarisation and variable pointing/resolution
Scanning technique	Side-looking, 15-45° off-nadir, swath 100 to 405 km, depending on operation mode - See table
Coverage/cycle	Global coverage in 5 day for the 'global monitoring' mode (if used for 70 % of the time); in longer periods for other operation modes, up to 3 months
Resolution	30 m to 1 km, depending on operation mode - See table
Resources	Mass: 832 kg - Power: 1400 W - Data rate: 100 Mbps

Operation mode	Resolution	Swath	Field of regard	Polarisation
Stripmap	30 m	100 km	485 km	HH or VV
ScanSAR alternating pol	30 m	100 km	485 km	VV/HH, HH/HV, VV/VH
ScanSAR wide swath	150 m	405 km	405 km	HH or VV
ScanSAR wide swath	150 m	405 km	405 km	HH or VV
ScanSAR global monitoring	1 km	405 km	405 km	HH or VV
Wave	30 m	5 x 5 km^2 imagettes sampled at 100 km intervals		HH or VV

Table 3 Main features of ASAR

1.2.3 Highlights of the algorithm

The baseline algorithm for SM-OBS-2 processing is described in ATDD-08. Only essential elements are highlighted here.

Fig. 08 illustrates the flow chart of the SM-OBS-2 processing chain. There is an off-line activity to prepare the disaggregation parameters and a real-time activity to exploit the satellite data for the product

In the off-line pre-processing step, Envisat ASAR Global Mode (ASAR GM) datasets are re-sampled to the geometry of the output product over a predefined European grid. All the parameters are stored in a European parameter database. When it comes to product generation itself with the software WARP-H, the disaggregated product is calculated with the restored European parameter database in near-real time.

The idea of the disaggregation approach is to use a temporal stability concept. This concept has been established originally in hydrology, but has been used in different applications as well. Introduced by Vauchaud et al. 1985[1], it is used to estimate representative soil moisture stations within a catchment area. With this method, the relation between a single local in-situ soil moisture station and the regional mean of

[1] Vauchaud G., A. Passerat de Silans, P. Balabanis and M. Vauclin, 1985: "Temporal stability of spatially measured soil water probability density function". *Soil Science Society of America* **49**: 822-828.

all in-situ soil moisture stations can be described. Since then the method has for example been used by Martínez-Fernández and Ceballos 2005[2] to describe the relation between local in-situ soil moisture data and regional soil moisture trends. If the spatial coverage of ASAR GM data is not sufficient for regions in Europe, the product SM-OBS-2 is not defined there (currently the case for UK, parts of the Benelux countries, Sicily and Corsica) mainly due to conflicting operating modes of the ENVISAT instruments.

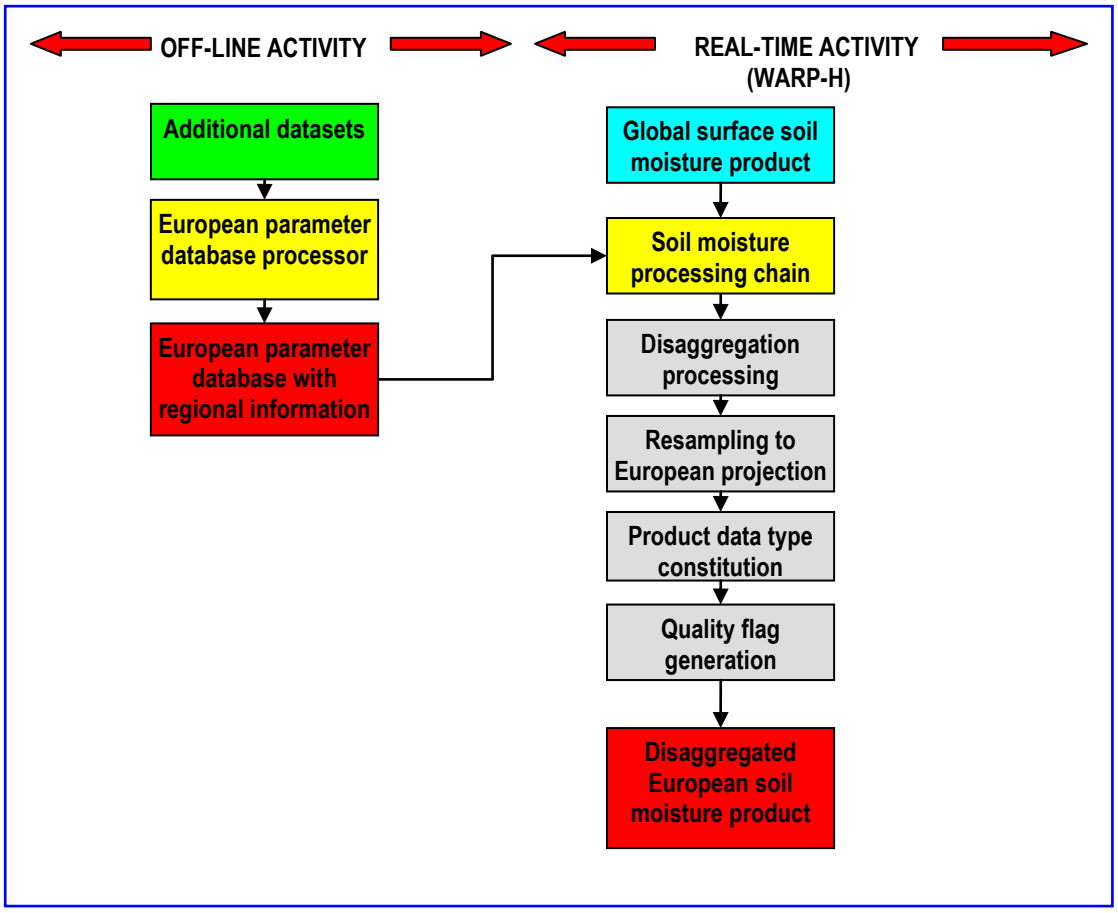

Figure 3 – Flow chart of the processing chain for the disaggregated soil moisture product

1.2.4 Architecture of the products generation chain

The architecture of the SM-OBS-2 product generation chain is shown in ***Fig. 09***. The figure includes mention of the primary source of satellite data, the Global surface soil moisture product generated by EUMETSAT and disseminated via EUMETCast; and of the source for disaggregation parameters, the ASAR instrument on Envisat, with data available from the ESA archive.

[2] Martínez-Fernández J. and A. Ceballos, 2005: "Mean soil moisture estimation using temporal stability analysis". *Journal of Hydrology* **312**: 28-38.

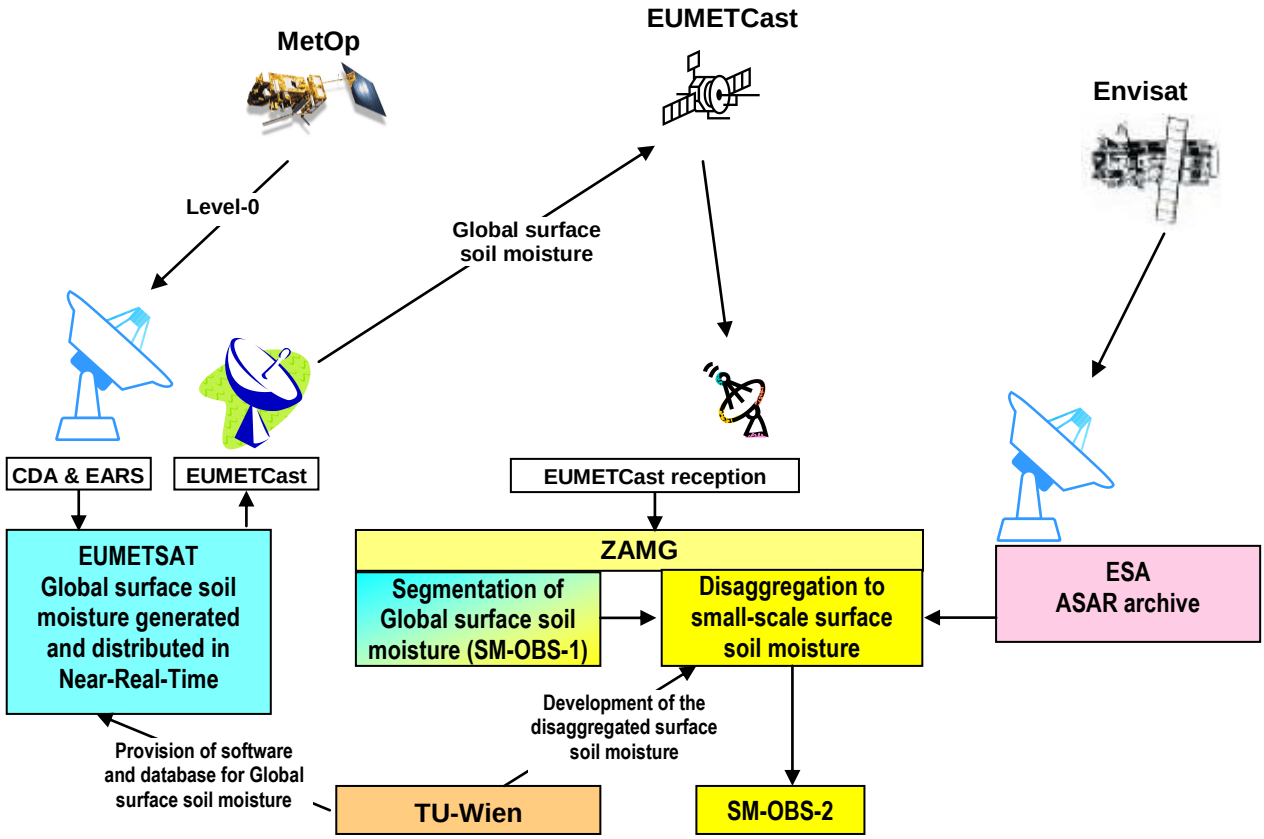

Figure 4 – - Conceptual architecture of the SM-OBS-2 production chain.

1.2.5 Product coverage and appearance

Fig. 10 shows an example of downscaled surface soil moisture at 1 km resolution for Europe representing a 3-minute strip of a full ASCAT orbit. The two sub-swaths can be clearly identified, no-data values (e.g. over the sea) are masked out.

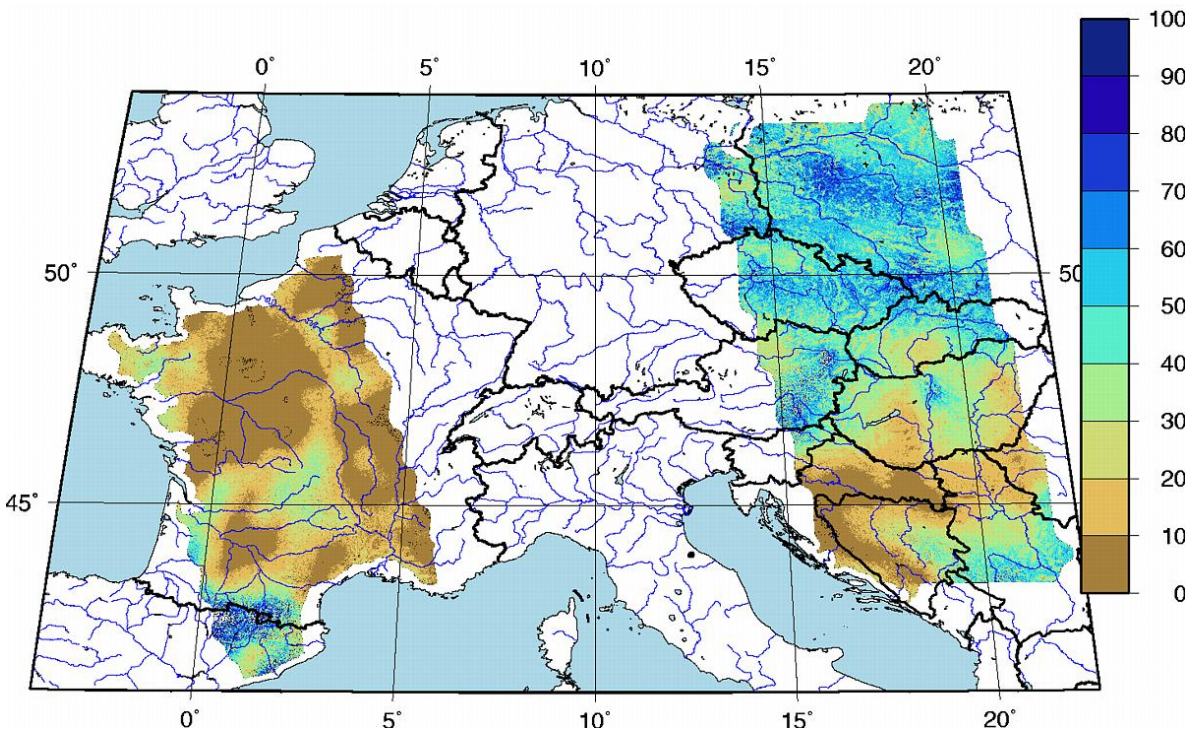

Figure 5 – - Example of small-scale surface soil moisture (SM-OBS-2) from ASCAT. Note the two side swaths (550 km each) and the 670 km gap in between. MetOp-A, 30 September 2009, 20:12 UTC.

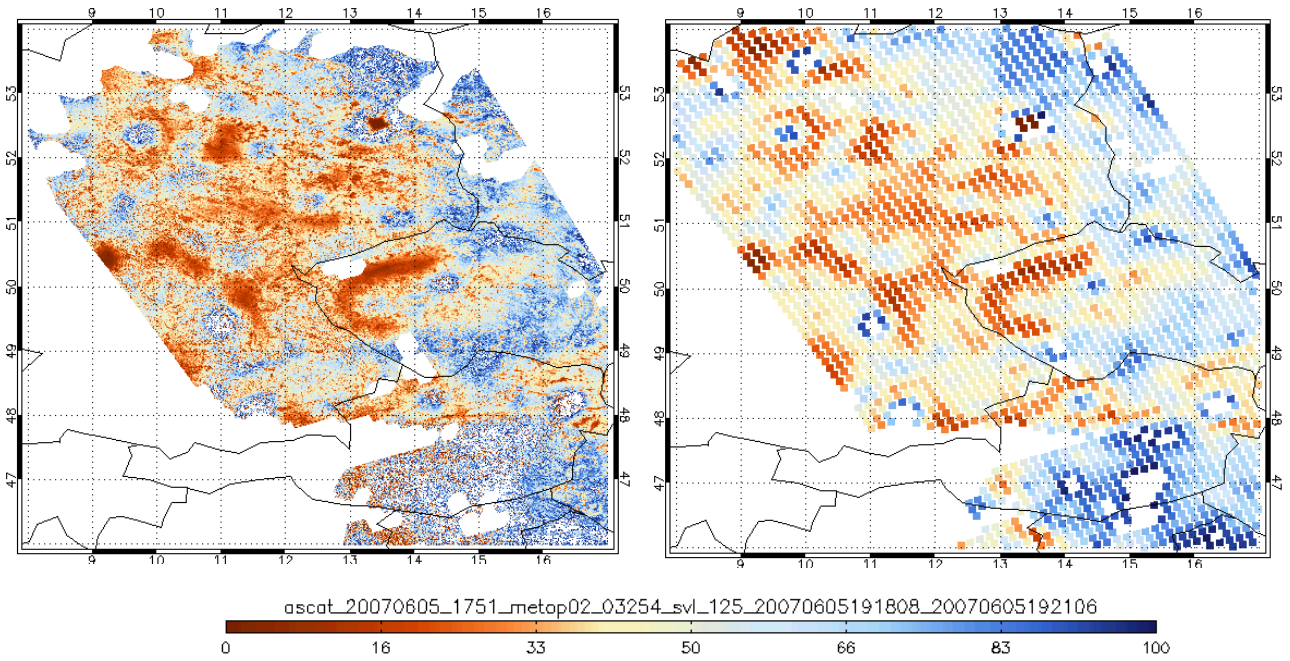

Figure 6 – - compares the 1-km sampled SM-OBS-2 with the 25-km original resolution of SM-OBS-1.

2 Product operational characteristics

2.1 Horizontal resolution and sampling

The *horizontal resolution (Δx)* is the convolution of several features (sampling distance, degree of independence of the information relative to nearby samples, …). To simplify matters, it is generally agreed to refer to the sampling distance between two successive product values, assuming that they carry forward reasonably independent information. The horizontal resolution descends from the instrument Instantaneous Field of View (*IFOV*), sampling distance (*pixel*), Modulation Transfer Function (*MTF*) and number of pixels to co-process for filtering out disturbing factors (e.g. clouds) or improving accuracy. It may be appropriate to specify both the resolution *Δx* associated to independent information, and the *sampling distance*, useful to minimise aliasing problems when data have to undertake resampling (e.g., for co-registration with other data).

In the case of SM-OBS-2, the effective resolution is controlled by the originating product, SM-OBS-1, and the disaggregation parameters. The effectiveness of disaggregation depends on the availability and the effectiveness of the disaggregation parameters, available at 500 m sampling (1 km resolution). The SM-OBS-2 resolution is therefore ***Δx = 1,*** the sampling distance is ***500 m***.

2.1.1 Vertical resolution if applicable

The *vertical resolution (Δz)* also is defined by referring to the vertical sampling distance between two successive product values, assuming that they carry forward reasonably independent information. The vertical resolution descends from the exploited remote sensing principle and the instrument number of channels, or spectral resolution. It is difficult to be estimated *a-priori*: it is generally evaluated *a-posteriori* by means of the validation activity.

The only product in H-SAF that provides profiles (below surface) is SM-ASS-1 (*Volumetric soil moisture (roots region) by scatterometer assimilation in NWP model*).

2.1.2 Observing cycle and time sampling

The *observing cycle (Δt)* is defined as the average time interval between two measurements over the same area. In general the area is, for GEO, the disk visible from the satellite, for LEO, the Globe. In the case of H-SAF we refer to the European area shown in Fig. 04. In the case of LEO, the observing cycle depends on the instrument swath and the number of satellites carrying the addressed instrument.

The ASCAT swath is 550 + 550 km on the two sides, with a 670 km gap in between. The gap left by ascending orbits is mostly filled by descending orbits. In average the observing cycle over Europe is ***Δt ~ 36 h***, improving with latitude. However, areas where disaggregation parameters are not available, are not processed, therefore the SM-OBS-2 maps leave several gaps of coverage. These gaps will progressively reduce along with progress of the ASAR coverage [and ultimately with the availability of the ESA/GMES Sentinel-1: launch scheduled in 2012]

2.1.3 Timeliness

The *timeliness (δ)* is defined as the time between observation taking and product available at the user site assuming a defined dissemination mean. The timeliness depends on the satellite transmission facilities, the availability of acquisition stations, the processing time required to generate the product and the reference dissemination means. In the case of H-SAF the future dissemination tool is EUMETCast, but currently we refer to the availability on the FTP site.

The product is generated shortly after reception of the Global product from EUMETSAT via EUMETCast, that has a timeliness of ~ 1.5 h. The processing time is less than 20 minutes. Adding 10 min for distribution we have: $\delta \sim 2\ h$.

2.1.4 Versioning history

The following table gives an overview about the operational product versions:

Version	Release date	Comments
1.01	20080228	Prototype parameter database (Eastern Europe).
1.02	20081106	Updates of parameter database to whole Europe.
1.03	20100517	Updated for major parts over Europe.
1.04	20110518	Updates (gap-filling) only over BeNeLux countries and Italy. Northern part of Belgium (Demer river catchment) extended, but with reduced quality (see note below).
1.05	20120412	Ethiopia and Kenya included as first African region.
1.06	20120701	Update over Italy. No updates over BeNeLux because only very few more new files were acquired.
1.07 (current)	20130704	Optimized processing chain; better results of interpolation in case of few valid measurements; now running on a virtual machine.

Table 4 Operational Product Versions

3 Product validation

3.1 Validation strategy

Whereas the previous operational characteristics have been evaluated on the base of system considerations (number of satellites, their orbits, access to the satellite) and instrument features (IFOV, swath, MTF and others), the evaluation of accuracy requires validation, i.e. comparison with the ground truth or with something assumed as “true”.

Calibration and validation of soil moisture observation from space is a hard work, especially because ground systems are essentially based on very sparse in-field measurements. Comparison with results of numerical models obviously suffer of the limited skill of NWP in predicting soil moisture (a very downstream product that passes through quantitative precipitation forecast, that certainly is not the most accurate product of NWP). A mixture of several techniques is generally used, and the results change with the climatic situation and the status of soil.

Detailed report of the product validation activity for product SM-OBS-2 is provided as document:

- PVR-08: Product Validation Report for SM-OBS-2.

In this PUM-08 only summary results are provided, mainly aiming at characterising the product quality under different geographical/climatological conditions (those in the countries of the participating validation Units) and different seasons.

3.2 Summary of results

Prototypes of SM-OBS-2 have been available since May 2009, and since then the product has been distributed and submitted for validation. User requirements for soil moisture observation have been stated in terms of RMSE (m^3 m^{-3}). The results reported in ***Table 08*** are split by countries and campaigns, separately for field measurements and comparison with the output of hydrological models. The following statistical scores are reported (for more information, see PVR-08):

- ME: Mean Error
- SD: Standard Deviation
- RMSE: Root Mean Square Error
- CC: Correlation coefficient.

SM-OBS-2		Region	V.	Period	N. of sites	ME (m^3 m^{-3})	SD (m^3 m^{-3})	RMSE (m^3 m^{-3})	CC
In-situ measurements	**Météo-France**	France (South-West)	2	01/2007-12/2008	13	-	-	-	0.86 (max)
	TU-Wien & Lippmann	Luxembourg (Bibeschbach)	2a	01/2007-05/2008	40	-	-	0.10 - 0.11	0.88 - 0.89
	LATMOS	France (Grand Morin)	2a	01/2007-12/2008	2	-	-	-	-
	LATMOS	Tunisia (Merguellil)	2a	01/2009-05/2009	1	-	-	-	-
	TU-Wien & CNR-IRPI	Luxembourg (Bibeschbach)	3b	01/2007-12/2008	2	Sfc: -0.18 Root: -0.18	-	Sfc: 0.29 Root: 0.14	Sfc: 0.58 Root: 0.84
	TU-Wien & CNR-IRPI	Italy (Tiber)	3b	01/2007-12/2008	1	Sfc: -0.03 Root: -0.04	-	Sfc: 0.30 Root: 0.15	Sfc: 0.46 Root: 0.85
Hydro. Model	**RMI**	Belgium (Demer	2a	01/2007-06/2009	709 (samples)	0.08	-	0.30	0.75
	RMI	Belgium (Ourthe)	2a	01/2007-06/2009	685 (samples)	0.21	-	0.29	0.76
	TU-Wien & CNR-IRPI	Italy (Tiber)	3a	01/2007-12/2008	1	Sfc: -0.12 Root: -0.12	-	Sfc: 0.22 Root: 0.14	Sfc: 0.74 Root: 0.84

Table 5 Statistical scores for SM-OBS-2

4 Product availability

4.1 Terms of Use

All H-SAF products are owned by EUMETSAT, and the EUMETSAT SAF Data Policy applies.

All intellectual property rights of the H-SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

4.2 General Information

To access the H-SAF products the user must register at the H-SAF Official Web Portal http://hsaf.meteoam.it/ from which it is possible to access to the "H-SAF Product Download Centre", which allows users to access data as described here following.

1) Access to data produced in the last 60 days must be made by the Official H-SAF FTP server ftp://ftphsaf.meteoam.it (to obtain user and password, please submit registration form on H-SAF Official Web Portal or contact the help desk at us_hsaf@meteoam.it) and via EUMETCAST, a multi-service dissemination system based on standard Digital Video Broadcast (DVB) technology (for more information http://www.eumetsat.int/).
2) The access to the archived data must be performed through an order process. There are two ways to place an order:
    a. the first (link) is a basic function provided directly from the H-SAF Web Portal. It provides all basic functions to carry out orders by selecting one or more products and setting for each selected product an expected time range;
    b. The second function https://eoportal.eumetsat.int/ allows access to EUMETSAT Data Centre. A registration to EUMETSAT portal is required. The EUMETSAT Data Center offers advanced functions of management and control of orders, among which the possibility to make geographical selection of products, to make the cloning of orders, and to monitor the status of the orders.

    In Both cases the orders placed will be submitted for approval and will be delivered within three working days.

Finally, quick-looks of the latest 20 maps can be viewed as PNG images or as an animated slideshow on the H-SAF Web Portal.

4.3 Formats and codes

SM-OBS-2 is coded as:

- the digital data: BUFR
- the image-like maps: PNG

In the directory "*utilities*", the folder *Bufr_decode* provides the instructions for reading the digital data. In addition, the output description of SM-OBS-2 is provided in the Appendix.

4.4 Description of the files

The data are available under

- Directory: *products*
- Sub-directory: *h08*
- Two folders:
    - h08_cur_mon_buf
    - h08_cur_mon_png

Table 09 summarises the situation and provides the information on the file structure.

URL: ftp://ftphsaf.meteoam.it	Credentials: register to hsaf.meteoam.it		directory: *products*
Product identifier: *h08*. Folders under h08:	h08_cur_mon_buf	digital data of current months	
	h08_cur_mon_png	Images of current months	
Files description of current month:	h08_yyyymmdd_hhmmss_satellite_nnnnn_ZAMG.buf.gz		digital data
	h08_yyyymmdd_hhmmss_satellite_nnnnn_ZAMG.png		image data
yyyymmdd: year, month, day hhmmss: hour, minute, second of first scan line (ascending: southernmost; descending: northernmost) satellite: name of the satellite (currently: metopa) nnnnn: orbit number			

Table 6 - Summary instructions for accessing SM-OBS-2 data

Annex 1: SM-OBS-2 Output description

The Soil moisture products are delivered in BUFR (Binary Universal Form for data Representation) format, which is a continuous bit stream made of sequence of octets encoded according to the current WMO tables. (A BUFR toolbox and a manual for the user can be found at the ECMWF homepage). A useful guide is given at the WMO-pages at:

http://www.wmo.int/pages/prog/www/WDM/Guides/Guide-binary-1A.html

The BUFR template valid at the time of this writing is:

1 006001 LONGITUDE (HIGH ACCURACY)
2 005001 LATITUDE (HIGH ACCURACY)
3 005001 LATITUDE (HIGH ACCURACY)
4 103000 (delayed replication of 4 BUFR descriptors)
5 031002 EXTENDED DELAYED DESCRIPTOR REPLICATION FACTOR
6 040001 SURFACE SOIL MOISTURE (MS)
7 040002 ESTIMATED ERROR IN SURFACE SOIL MOISTURE
8 040005 SOIL MOISTURE CORRECTION FLAG
9 040006 SOIL MOISTURE PROCESSING FLAG

Each of these telegrams represents an image column. Taking into account the results of the preceding, 120 of these telegrams are packed together in a BUFR „multi subset“.

Following tables show the possible values for flags 40005 and 40006, according to WMO definitions. Yet, only values highlighted in red are at present relevant for the 1km surface soil moisture product.

Bit No.	Meaning
1	Soil moisture between -20% and 0%
2	Soil moisture between 100% and 120%
3	Correction of wet backscatter reference
4	Correction of dry backscatter reference
5	Correction of volume scattering in sand
6-7	Reserved
All 8	Missing value

Table 7 - The WMO codes for BUFR flag No. 40005 - Soil moisture correction flags.

NOTE: The nominal range for the surface soil moisture is 0% - 100%. In extreme cases, the extrapolated backscatter at 40 degrees incidence angle may exceed the dry or the wet backscatter reference. In these cases, the value provided by the measurement process of surface soil moisture is, respectively, less than 0% or more than 100%.

Bit No.	Meaning
1	Not soil
2	Sensitivity to soil moisture below limit
3	Azimuthal noise above limit
4	Backscatter Fore-Aft beam out of range
5	Slope Mid-Fore beam out of range
6	Slope Mid-Aft beam out of range
7	Soil moisture below -20%
8	Soil moisture above 120%

9-15	Reserved
All 16	Missing value

Table 8 The WMO codes for BUFR flag No. 40006 - Soil moisture processing flags.

NOTE: See Note under Flag No. 40005 in previous table

The first telegram in the operational BUFR files is different and provides the user with some information useful for deciding whether the file actually has some data of interest in it and is worth further decoding (in particular, the prologue reports the geographical coverage of the dataset). Template of the prologue:

1 025061 SOFTWARE IDENTIFICATION AND VERSION NUMBER
2 025062 DATABASE IDENTIFICATION
3 006002 LONGITUDE (COARSE ACCURACY)
4 006002 LONGITUDE (COARSE ACCURACY)
5 005002 LATITUDE (COARSE ACCURACY)
6 005002 LATITUDE (COARSE ACCURACY)

For those users which are not so familiar with BUFR a FORTRAN program which converts the operational 1 km soil moisture product (SM-OBS 2) file into netCDF is attached here:

```
 PROGRAM BUFR2NETCDF

!
! PURPOSE: DECODE THE OPERATIONAL 1 KM - SOIL MOISTURE PRODUCT IN BUFR FORMAT,
!        RE-ENCODE IN netCDF FORMAT
! EXTERNALS: BUFREX, BUSEL2, BUS0123, PBBUFR, PBOPEN, PBCLOSE
! COMPILATION: f90 -o bufr2netcdf bufr2netcdf.F90 -L$NETCDF_libdir -lnetcdf -L$HDF_libdir -lhdf5_hl -lhdf5 -L$BUFR_libdir -lbufr
! CALL: bufr2netcdf <BUFR file's name>
! OUTPUT: NetCDF file, with extension (i.e. everything after the last dot) replaced by 'nc'
!       (h08_20090816_105100_metopa_14658_ZAMG.buf becomes h08_20090816_105100_metopa_14658_ZAMG.nc)
! AUTHOR: Alexander Jann / ZAMG
! DATE: 04/11/09 (+ bug fix in 08/11)
!

 USE netcdf
 IMPLICIT NONE
 INTEGER :: I, INDEX1D, INDEX2D, ERR, SUBSET_NR, JUMP, JUMP_SM, N, NLAT, NLON, NR_PIXELS, UNIT

! BUFR
 INTEGER, PARAMETER ::  JSUP=9,  JSEC0=3,     JSEC1=40,    JSEC2=4096  , JSEC3=4,  &
    JSEC4=2, JELEM=160000, JBUFL=512000, KELEM=160000, KVALS=4096000, JBYTE=440000

 INTEGER :: KSUP(JSUP), KSEC0(JSEC0), KSEC1(JSEC1)
 INTEGER :: KSEC2(JSEC2), KSEC3(JSEC3), KSEC4(JSEC4)
 INTEGER :: KBUFL, KDLEN, KEL, KTDLEN, KTDEXL
 INTEGER, DIMENSION(JBUFL) :: KBUFF
 REAL*8,  DIMENSION(KVALS) :: VALUES

 INTEGER, DIMENSION(JELEM) :: KTDLST, KTDEXP
 CHARACTER (LEN=64), DIMENSION(KELEM) :: CNAMES
 CHARACTER (LEN=24), DIMENSION(KELEM) :: CUNITS
 CHARACTER (LEN=80), DIMENSION(KELEM) :: CVALS


! IDs for the netCDF file, dimensions, and variables...
 INTEGER   :: NCID, LON_DIMID, LAT_DIMID, DIMIDS(2)
 INTEGER   :: LAT_VARID, LON_VARID
 INTEGER   :: SOMO_VARID, SOMO_ERR_VARID, SOMO_FLAG5_VARID, SOMO_FLAG6_VARID
! ...ranges...
 REAL     :: SOMO_RANGE(2) = (/0., 100./)
 INTEGER*2 :: FLAG_RANGE(2) = (/0, 255/)
! ...names.
 CHARACTER (LEN = *), PARAMETER :: LAT_NAME = "latitude", LON_NAME = "longitude"
 CHARACTER (LEN = *), PARAMETER :: UNITS = "units", SOMO_UNITS = "%"
```

```
  CHARACTER (LEN = *), PARAMETER :: LAT_UNITS = "degrees_north", LON_UNITS = "degrees_east"

! SM data
  REAL, DIMENSION(:), ALLOCATABLE    ::  SOMO, SOMO_ERR, LAMBDA, PHI
  INTEGER*2, DIMENSION(:), ALLOCATABLE  ::  FLAG_40005, FLAG_40006
  CHARACTER (LEN=255) :: IFILNAM, OFILNAM

  DATA KSEC0,KSEC2,KSEC3,KSEC4,KTDLST &
    /JSEC0*0,JSEC2*0,JSEC3*0,JSEC4*0,JELEM*0/

! 1. Open BUFR file
! ---------------------------------------

  CALL GETARG(1,IFILNAM)
  ERR=0
  CALL PBOPEN(UNIT,IFILNAM,'R',ERR)
  IF ( ERR == -1 ) STOP 'OPEN FAILED'
  IF ( ERR == -2 ) STOP 'INVALID FILE NAME'
  IF ( ERR == -3 ) STOP 'INVALID OPEN MODE SPECIFIED'

! 2. Decode prologue
! ---------------------------------------

  ERR=0
  CALL PBBUFR(UNIT,KBUFF,JBYTE*4,KBUFL,ERR)
  IF (ERR /= 0) STOP 'cannot even read the prologue :-('
  KBUFL=KBUFL/4+1
  CALL BUS0123(KBUFL, KBUFF, KSUP, KSEC0, KSEC1, KSEC2, KSEC3, ERR)
  KEL=KVALS/KSEC3(3)
  IF (KEL > KELEM) KEL=KELEM

! Expand BUFR message.
  CALL BUFREX(KBUFL, KBUFF, KSUP, KSEC0, KSEC1, KSEC2, KSEC3, KSEC4, &
    KEL, CNAMES, CUNITS, KVALS, VALUES, CVALS, ERR)

  NLON=NINT((VALUES(4)-VALUES(3))/0.00416667) ! maximum; # of columns may actually be less
  NLAT=NINT((VALUES(6)-VALUES(5))/0.00416667)
  NR_PIXELS=NLON*NLAT

  ALLOCATE(SOMO(1:NR_PIXELS))
  ALLOCATE(SOMO_ERR(1:NR_PIXELS))
  ALLOCATE(FLAG_40005(1:NR_PIXELS))
  ALLOCATE(FLAG_40006(1:NR_PIXELS))
  ALLOCATE(LAMBDA(1:NLON))
  ALLOCATE(PHI(1:NLAT))

! 3.  Decode actual soil moisture data.
! ---------------------------------------

  INDEX1D=1
  INDEX2D=1

MSSLOOP: DO
    KBUFL=0
    CALL PBBUFR(UNIT,KBUFF,JBYTE*4,KBUFL,ERR)
    IF (ERR == -1) THEN
      CALL PBCLOSE(UNIT,ERR)
      EXIT MSSLOOP
    ENDIF
    IF (ERR == -2) STOP 'FILE HANDLING PROBLEM'
    IF (ERR == -3) STOP 'ARRAY TOO SMALL FOR PRODUCT'

    N=N+1
    KBUFL=KBUFL/4+1

    CALL BUS0123(KBUFL, KBUFF, KSUP, KSEC0, KSEC1, KSEC2, KSEC3, ERR)
    IF (ERR /= 0) THEN
      PRINT*,'ERROR IN BUS0123: ',ERR, 'FOR MESSAGE NUMBER ',N
      ERR=0
```

```
      CYCLE MSSLOOP
    ENDIF
    KEL=KVALS/KSEC3(3)
    IF (KEL > KELEM) KEL=KELEM

!  Expand BUFR message.
    CALL BUFREX(KBUFL, KBUFF, KSUP, KSEC0, KSEC1, KSEC2, KSEC3, KSEC4, &
     KEL, CNAMES, CUNITS, KVALS, VALUES, CVALS, ERR)
    IF (ERR /= 0) CALL EXIT(2)

ISSLOOP:  DO SUBSET_NR=0,KSUP(6)-1
      JUMP=SUBSET_NR*KEL
      CALL BUSEL2(SUBSET_NR+1,KEL,KTDLEN,KTDLST,KTDEXL,KTDEXP,CNAMES, &
       CUNITS,ERR)
      LAMBDA(INDEX1D)=VALUES(JUMP+1)
      IF (INDEX1D == 1) THEN
        DO I=1,NLAT
          PHI(I)=VALUES(JUMP+2)+0.00416667*(I-1)
        END DO
      ENDIF
      INDEX1D=INDEX1D+1
!   Resolve replication
      JUMP_SM=JUMP+5
      DO I=1,VALUES(JUMP+4)
        SOMO(INDEX2D)=VALUES(JUMP_SM)
        SOMO_ERR(INDEX2D)=VALUES(JUMP_SM+1)
        FLAG_40005(INDEX2D)=VALUES(JUMP_SM+2)
        IF (VALUES(JUMP_SM+3) > 65535.) THEN
          FLAG_40006(INDEX2D)=255
        ELSE
          FLAG_40006(INDEX2D)=VALUES(JUMP_SM+3)
        ENDIF
        JUMP_SM=JUMP_SM+4
        INDEX2D=INDEX2D+1
      END DO
    END DO ISSLOOP
  END DO MSSLOOP

!   4. Create the netCDF file and variables.
!  ----------------------------------------

   OFILNAM=IFILNAM(1:SCAN(IFILNAM,'.',.TRUE.))//'nc'
   CALL CHECK( NF90_CREATE(OFILNAM, NF90_HDF5, NCID) )

! Define the dimensions.
   NLON=INDEX1D-1
   CALL CHECK( NF90_DEF_DIM(NCID, LAT_NAME, NLAT, LAT_DIMID) )
   CALL CHECK( NF90_DEF_DIM(NCID, LON_NAME, NLON, LON_DIMID) )

! Define the coordinate variables. They will hold the coordinate
! information, that is, the latitudes and longitudes. A varid is
! returned for each.
   CALL CHECK( NF90_DEF_VAR(NCID, LAT_NAME, NF90_FLOAT, LAT_DIMID, LAT_VARID) )
   CALL CHECK( NF90_DEF_VAR(NCID, LON_NAME, NF90_FLOAT, LON_DIMID, LON_VARID) )

! Assign units attributes to coordinate var data. This attaches a
! text attribute to each of the coordinate variables, containing the
! units.
   CALL CHECK( NF90_PUT_ATT(NCID, LAT_VARID, UNITS, LAT_UNITS) )
   CALL CHECK( NF90_PUT_ATT(NCID, LON_VARID, UNITS, LON_UNITS) )

! The dimids array is used to pass the dimids of the dimensions of
!     the netCDF variables. All netCDF variables we are
!     creating share the same two dimensions.
   DIMIDS = (/ LON_DIMID, LAT_DIMID /)

! Define the netCDF variables for the soil moisture data.
   CALL CHECK( NF90_DEF_VAR(NCID, "soil_moisture", NF90_FLOAT, DIMIDS, SOMO_VARID) )
   CALL CHECK( NF90_PUT_ATT(NCID, SOMO_VARID, UNITS, SOMO_UNITS) )
```

```
  CALL CHECK( NF90_PUT_ATT(NCID, SOMO_VARID, "valid_range", SOMO_RANGE) )
  CALL CHECK( NF90_DEF_VAR_DEFLATE(NCID, SOMO_VARID, 1, 1, 9) )

  CALL CHECK( NF90_DEF_VAR(NCID, "soil_moisture_error", NF90_FLOAT, DIMIDS, SOMO_ERR_VARID) )
  CALL CHECK( NF90_PUT_ATT(NCID, SOMO_ERR_VARID, UNITS, SOMO_UNITS) )
  CALL CHECK( NF90_PUT_ATT(NCID, SOMO_ERR_VARID, "valid_range", SOMO_RANGE) )
  CALL CHECK( NF90_DEF_VAR_DEFLATE(NCID, SOMO_ERR_VARID, 1, 1, 9) )

  CALL CHECK( NF90_DEF_VAR(NCID, "soil_moisture_correction_flag", NF90_SHORT, DIMIDS, SOMO_FLAG5_VARID) )
  CALL CHECK( NF90_PUT_ATT(NCID, SOMO_FLAG5_VARID, "valid_range", FLAG_RANGE) )
  CALL CHECK( NF90_DEF_VAR_DEFLATE(NCID, SOMO_FLAG5_VARID, 1, 1, 9) )

  CALL CHECK( NF90_DEF_VAR(NCID, "soil_moisture_processing_flag", NF90_SHORT, DIMIDS, SOMO_FLAG6_VARID) )
  CALL CHECK( NF90_PUT_ATT(NCID, SOMO_FLAG6_VARID, "valid_range", FLAG_RANGE) )
  CALL CHECK( NF90_DEF_VAR_DEFLATE(NCID, SOMO_FLAG6_VARID, 1, 1, 9) )

! End define mode.
  CALL CHECK( NF90_ENDDEF(NCID) )


!   5. Write the netCDF file, clean up and leave.
! ---------------------------------------------

! Write the coordinate variable data. This will put the latitudes
! and longitudes of our data grid into the netCDF file.
  CALL CHECK( NF90_PUT_VAR(NCID, LAT_VARID, PHI) )
  CALL CHECK( NF90_PUT_VAR(NCID, LON_VARID, LAMBDA(1:NLON)) )

! Write the soil moisture data to the netCDF file
  CALL CHECK( NF90_PUT_VAR(NCID, SOMO_VARID, TRANSPOSE(RESHAPE(SOMO(1:INDEX2D-1),(/NLAT, NLON/)))) )
  CALL CHECK( NF90_PUT_VAR(NCID, SOMO_ERR_VARID, TRANSPOSE(RESHAPE(SOMO_ERR(1:INDEX2D-1),(/NLAT, NLON/)))) )
  CALL CHECK( NF90_PUT_VAR(NCID, SOMO_FLAG5_VARID, TRANSPOSE(RESHAPE(FLAG_40005(1:INDEX2D-1),(/NLAT, NLON/)))) )
  CALL CHECK( NF90_PUT_VAR(NCID, SOMO_FLAG6_VARID, TRANSPOSE(RESHAPE(FLAG_40006(1:INDEX2D-1),(/NLAT, NLON/)))) )

! Close the file.
  CALL CHECK( NF90_CLOSE(NCID) )

  DEALLOCATE(SOMO_ERR)
  DEALLOCATE(SOMO)
  DEALLOCATE(FLAG_40005)
  DEALLOCATE(FLAG_40006)
  DEALLOCATE(LAMBDA)
  DEALLOCATE(PHI)
  WRITE(*,*) "*** SUCCESS in writing ",OFILNAM

CONTAINS
  SUBROUTINE CHECK(STATUS)
  INTEGER, INTENT ( IN) :: STATUS
  IF (STATUS /= NF90_NOERR) THEN
    WRITE(*,*) NF90_STRERROR(STATUS)
    STOP 2
  END IF
  END SUBROUTINE CHECK
END PROGRAM
```

Annex 2: BUFR decoding example

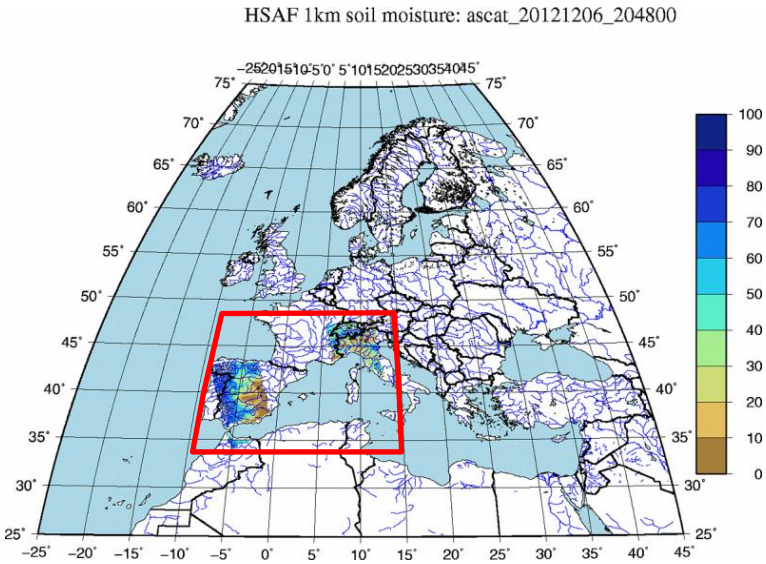

Figure 7: Example file h08_20121206_204800_metopa_31826_ZAMG.buf used for decoding.

1. Schematic data organisation

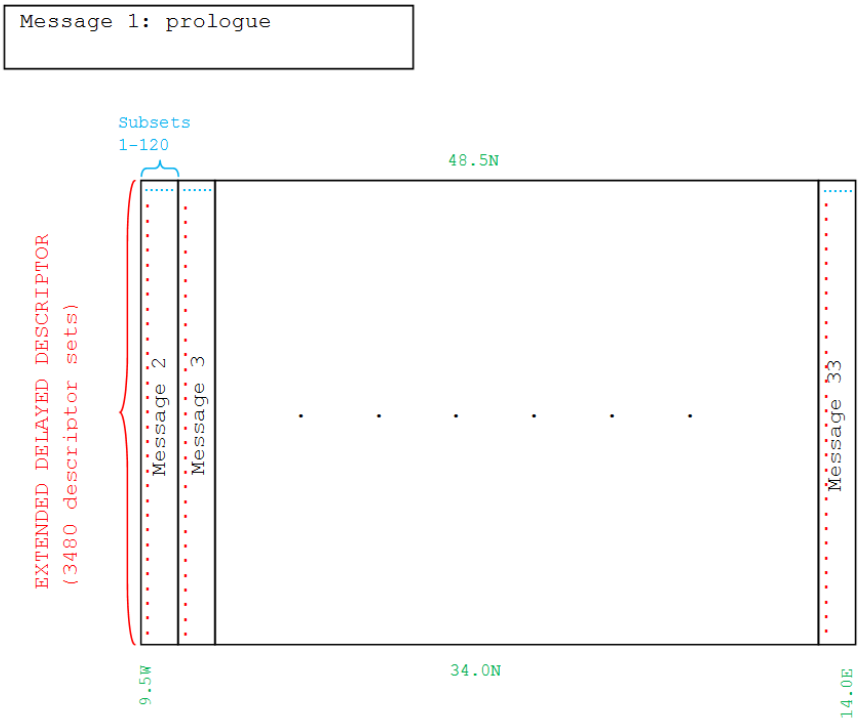

Figure 8: Schematic organisation of the product.

The data coverage is marked with the red box in the map figure above. The colours of the schematic correspond to the colours in the following text for our example file. This BUFR file contains 34 messages (starting 34 times with the four letters "BUFR"). The number of messages is variable. Message 1 is always the "prologue" (like a header information), while the following messages (in our case 2-33) contain the actual data. Each message is subdivided into "Sections".

2. Message 1: the "prologue"

The prologue tells you the coarse accuracy coordinates of the image coverage: 9.5W to 14E and 34N to 48.5N, with the software WH_NRT 1.1 in version 1.06.

```
Section 0
Length of Section 0:  8 byte(s)
Total length of BUFR message: 88 byte(s)
BUFR edition number:  4

Section 1
Length of Section 1:  22 byte(s)
Originating subcentre: 0
Originating centre:   0
Update sequence number:       1
Flag (Presence of section 2): 0
Local table version number:   0
Data category: 0
Data subcategory:     0
Local data sub-category:      0
Year:  2012
Month: 12
Day:   6
Hour:  20
Minute: 48
Second: 0
BUFR master table:    0
BUFR master table version number:    13

Section 3
Length of Section 3:  28 byte(s)
Reserved:      0
Number of data subsets:       1
Data type/data compression:   0

Data descriptors (unexpanded)
1       025061
2       201129
3       202130
4       025062
5       202000
6       201000
7       006002
8       006002
9       005002
10      005002

Data descriptors (expanded)
1       025061  SOFTWARE IDENTIFICATION AND VERSION NUMBER
2       025062  DATABASE IDENTIFICATION
3       006002  LONGITUDE (COARSE ACCURACY)
4       006002  LONGITUDE (COARSE ACCURACY)
5       005002  LATITUDE (COARSE ACCURACY)
6       005002  LATITUDE (COARSE ACCURACY)

Subset 1
1       SOFTWARE IDENTIFICATION AND VERS     0.10120000000000E+004 CCITTIA5 WH_NRT 1.1
2       DATABASE IDENTIFICATION       0.10600000000000E+001 NUMERIC
3       LONGITUDE (COARSE ACCURACY)   -0.95000000000000E+001        DEGREE
4       LONGITUDE (COARSE ACCURACY)   0.14000000000000E+002 DEGREE
5       LATITUDE (COARSE ACCURACY)    0.34000000000000E+002 DEGREE
6       LATITUDE (COARSE ACCURACY)    0.48500000000000E+002 DEGREE
```

3. Message 2: the actual start of data

The next messages now constitute the actual data stream. The data are listed column-wise from west to east, organised in 120 element groups (120 is fixed for all BUFR files). The descriptor EXTENDED DELAYED DESCRIPTOR tells you that the next descriptors (SURFACE SOIL MOISTURE to SOIL MOISTURE PROCESSING FLAG) are always repeated in a group of 4 (quadruple). The value 3480 (this number is variable) tells you that the repetition is done 3480 times. Coordinates are given now in high accuracy. The next 3480 quadruples are related to the first image column at 8.49792W, which starts at 34.0021N and ends at 48.4979N. Subset 2

lists the next 3480 quadruples for the next column at 8.49375W and so forth. In the end you filled a matrix with 120*33=3960 elements (x-direction) times 3480 elements (y-direction) with a total of 13 780 800 records.

```
Section 0
Length of Section 0:          8 byte(s)
Total length of BUFR message: 252394 byte(s)
BUFR edition number:          4

Section 1
Length of Section 1:              22 byte(s)
Originating subcentre:            0
Originating centre:               0
Update sequence number:           1
Flag (Presence of section 2):     0
Local table version number:       0
Data category:                    0
Data subcategory:                 0
Local data sub-category:          0
Year:                             2012
Month:                            12
Day:                              6
Hour:                             20
Minute:                           48
Second:                           0
BUFR master table:                0
BUFR master table version number: 13

Section 3
Length of Section 3:        26 byte(s)
Reserved:                   0
Number of data subsets:     120
Data type/data compression: 64

Data descriptors (unexpanded)
1 006001
2 005001
3 005001
4 104000
5 031002
6 040001
7 040002
8 040005
9 040006

Subset 1
1 LONGITUDE (HIGH ACCURACY)         -0.84979200000000E+001 DEGREE
2 LATITUDE (HIGH ACCURACY)          0.34002080000000E+002  DEGREE
3 LATITUDE (HIGH ACCURACY)          0.48497920000000E+002  DEGREE
4 EXTENDED DELAYED DESCRIPTOR REPL 0.34800000000000E+004  NUMERIC
5 SURFACE SOIL MOISTURE (MS)        MISSING                %
6 ESTIMATED ERROR IN SURFACE SOIL   MISSING                %
7 SOIL MOISTURE CORRECTION FLAG     0.00000000000000E+000  FLAG TABLE 40005
8 SOIL MOISTURE PROCESSING FLAG     MISSING                FLAG TABLE 40006
```

[...] (the 4 descriptors are repeated 4*3480=13 920 lines in here)

```
13921 SURFACE SOIL MOISTURE (MS)      MISSING                %
13922 ESTIMATED ERROR IN SURFACE SOIL MISSING                %
```

```
13923 SOIL MOISTURE CORRECTION FLAG   0.00000000000000E+000 FLAG TABLE 40005
13924 SOIL MOISTURE PROCESSING FLAG   MISSING               FLAG TABLE 40006
```

[...]

```
Subset 120
```

[...]

4. Message 3-33: the rest of the data

Similar to previous section.

Annex 3: Introduction to H-SAF

The EUMETSAT Satellite Application Facilities

H-SAF is part of the distributed application ground segment of the "*European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)*". The application ground segment consists of a "*Central Application Facilities*" located at EUMETSAT Headquarters, and a network of eight "*Satellite Application Facilities (SAFs)*", located and managed by EUMETSAT Member States and dedicated to development and operational activities to provide satellite-derived data to support specific user communities (see Figure 9):

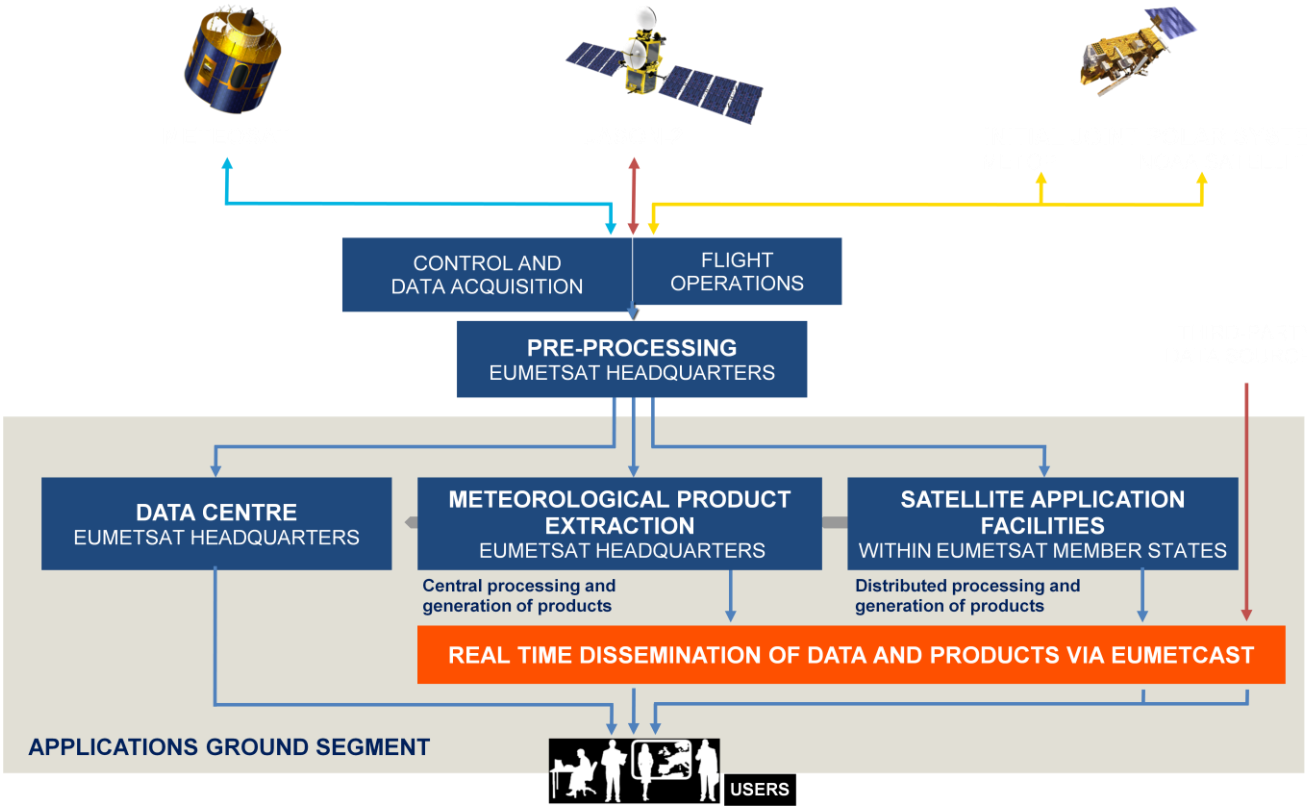

Figure 9: Conceptual scheme of the EUMETSAT Application Ground Segment

Figure 10, here following, depicts the composition of the EUMETSAT SAF network, with the indication of each SAF's specific theme and Leading Entity.

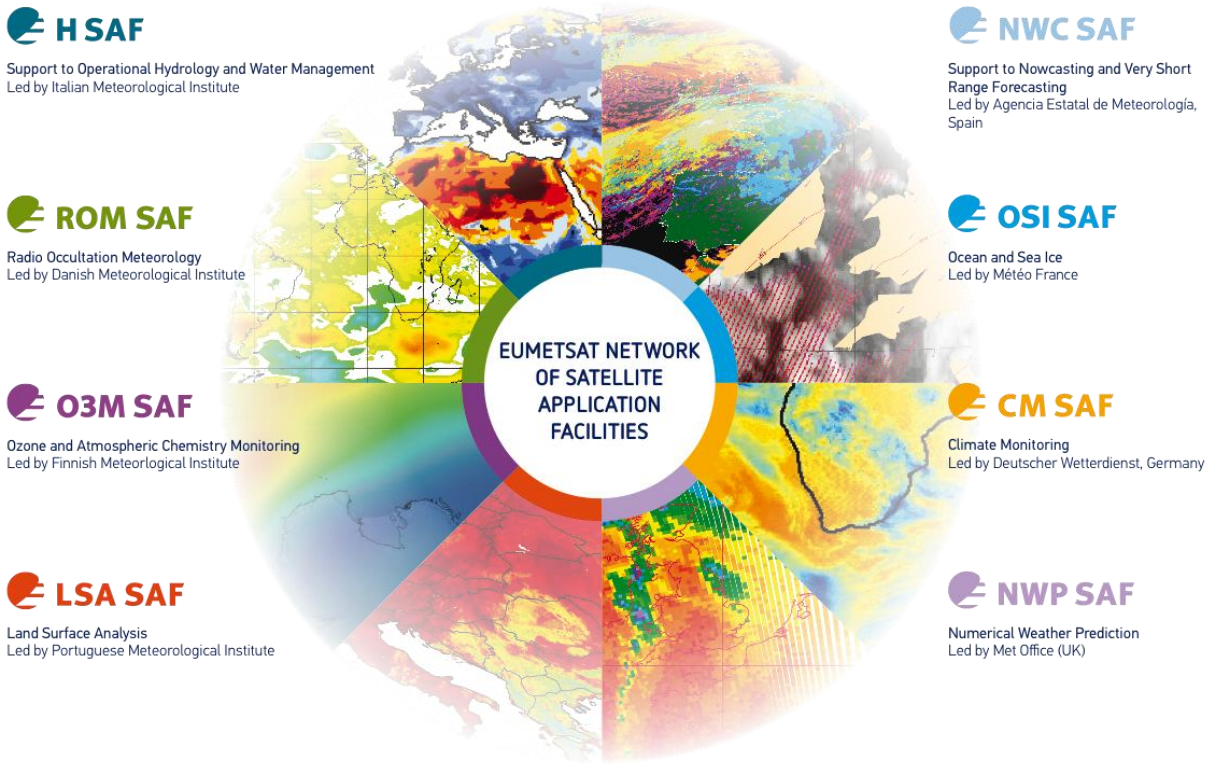

Figure 10: Current composition of the EUMETSAT SAF Network

Purpose of the H-SAF

The main objectives of H-SAF are:

a. ***to provide new satellite-derived products*** from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology, by generating, centralizing, archiving and disseminating the identified products:

- precipitation (liquid, solid, rate, accumulated);
- soil moisture (at large-scale, at local-scale, at surface, in the roots region);
- snow parameters (detection, cover, melting conditions, water equivalent);

b. ***to perform independent validation of the usefulness of the products*** for fighting against floods, landslides, avalanches, and evaluating water resources; the activity includes:

- downscaling/upscaling modelling from observed/predicted fields to basin level;
- fusion of satellite-derived measurements with data from radar and raingauge networks;
- assimilation of satellite-derived products in hydrological models;
- assessment of the impact of the new satellite-derived products on hydrological applications.

Products / Deliveries of the H-SAF

For the full list of the Operational products delivered by H-SAF, and for details on their characteristics, please see H-SAF website hsaf.meteoam.it.

All products are available via EUMETSAT data delivery service (EUMETCast, http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html), or via ftp download; they are also published in the H-SAF website hsaf.meteoam.it.

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System Overview

H-SAF is lead by the Italian Air Force Meteorological Service (ITAF USAM) and carried on by a consortium of 21 members from 11 countries (see website: hsaf.meteoam.it for details)

Two major areas can be distinguished within the H-SAF system context:

- Product generation area
- Central Services area (for data archiving, dissemination, catalogue and any other centralized services)
- Validation services area which includes Quality Monitoring/Assessment and Hydrological Impact Validation.

Products generation area is composed of 5 processing centres physically deployed in 5 different countries; these are:

- for precipitation products: ITAF CNMCA (Italy)
- for soil moisture products: ZAMG (Austria), ECMWF (UK)
- for snow products: TSMS (Turkey), FMI (Finland)

Central area provides systems for archiving and dissemination; located at ITAF CNMCA (Italy), it is interfaced with the production area through a front-end, in charge of product collecting.

A central archive is aimed to the maintenance of the H-SAF products; it is also located at ITAF CNMCA.

Validation services provided by H-SAF consists of:

- Hydrovalidation of the products using models (hydrological impact assessment);
- Product validation (Quality Assessment and Monitoring).

Both services are based on country-specific activities such as impact studies (for hydrological study) or product validation and value assessment.

Hydrovalidation service is coordinated by IMWM (Poland), whilst Quality Assessment and Monitoring service is coordinated by DPC (Italy): The Services' activities are performed by experts from the national meteorological and hydrological Institutes of Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey, and from ECMWF.

Annex 4: Acronyms

AMSU	Advanced Microwave Sounding Unit (on NOAA and MetOp)
AMSU-A	Advanced Microwave Sounding Unit - A (on NOAA and MetOp)
AMSU-B	Advanced Microwave Sounding Unit - B (on NOAA up to 17)
ATDD	Algorithms Theoretical Definition Document
AU	Anadolu University (in Turkey)
BfG	Bundesanstalt für Gewässerkunde (in Germany)
CAF	Central Application Facility (of EUMETSAT)
CDOP	Continuous Development-Operations Phase
CESBIO	Centre d'Etudes Spatiales de la BIOsphere (of CNRS, in France)
CM-SAF	SAF on Climate Monitoring
CNMCA	Centro Nazionale di Meteorologia e Climatologia Aeronautica (in Italy)
CNR	Consiglio Nazionale delle Ricerche (of Italy)
CNRS	Centre Nationale de la Recherche Scientifique (of France)
DMSP	Defense Meteorological Satellite Program
DPC	Dipartimento Protezione Civile (of Italy)
EARS	EUMETSAT Advanced Retransmission Service
ECMWF	European Centre for Medium-range Weather Forecasts
EDC	EUMETSAT Data Centre, previously known as U-MARF
EUM	Short for EUMETSAT
EUMETCast	EUMETSAT's Broadcast System for Environmental Data
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
GEO	Geostationary Earth Orbit
GRAS-SAF	SAF on GRAS Meteorology
HDF	Hierarchical Data Format
HRV	High Resolution Visible (one SEVIRI channel)
H-SAF	SAF on Support to Operational Hydrology and Water Management
IDL©	Interactive Data Language
IFOV	Instantaneous Field Of View
IMWM	Institute of Meteorology and Water Management (in Poland)
IPF	Institut für Photogrammetrie und Fernerkundung (of TU-Wien, in Austria)
IPWG	International Precipitation Working Group
IR	Infra Red
IRM	Institut Royal Météorologique (of Belgium) (alternative of RMI)
ISAC	Istituto di Scienze dell'Atmosfera e del Clima (of CNR, Italy)
ITU	İstanbul Technical University (in Turkey)
LATMOS	Laboratoire Atmosphères, Milieux, Observations Spatiales (of CNRS, in France)
LEO	Low Earth Orbit
LSA-SAF	SAF on Land Surface Analysis
LST	Local Satellite Time (if referred to time) or Land Surface Temperature (if referred to temperature)
Météo France	National Meteorological Service of France
METU	Middle East Technical University (in Turkey)
MHS	Microwave Humidity Sounder (on NOAA 18 and 19, and on MetOp)
MSG	Meteosat Second Generation (Meteosat 8, 9, 10, 11)
MVIRI	Meteosat Visible and Infra Red Imager (on Meteosat up to 7)
MW	Micro Wave
NEΔT	Net Radiation
NESDIS	National Environmental Satellite, Data and Information Services
NMA	National Meteorological Administration (of Romania)
NOAA	National Oceanic and Atmospheric Administration (Agency and satellite)
NWC-SAF	SAF in support to Nowcasting & Very Short Range Forecasting
NWP	Numerical Weather Prediction
NWP-SAF	SAF on Numerical Weather Prediction
O3M-SAF	SAF on Ozone and Atmospheric Chemistry Monitoring
OMSZ	Hungarian Meteorological Service

ORR	Operations Readiness Review
OSI-SAF	SAF on Ocean and Sea Ice
PDF	Probability Density Function
PEHRPP	Pilot Evaluation of High Resolution Precipitation Products
Pixel	Picture element
PMW	Passive Micro-Wave
PP	Project Plan
PR	Precipitation Radar (on TRMM)
PUM	Product User Manual
PVR	Product Validation Report
RMI	Royal Meteorological Institute (of Belgium) (alternative of IRM)
RR	Rain Rate
RU	Rapid Update
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager (on Meteosat from 8 onwards)
SHMÚ	Slovak Hydro-Meteorological Institute
SSM/I	Special Sensor Microwave / Imager (on DMSP up to F-15)
SSMIS	Special Sensor Microwave Imager/Sounder (on DMSP starting with S-16)
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
T_{BB}	Equivalent Blackbody Temperature (used for IR)
TKK	Teknillinen korkeakoulu (Helsinki University of Technology)
TMI	TRMM Microwave Imager (on TRMM)
TRMM	Tropical Rainfall Measuring Mission UKMO
TSMS	Turkish State Meteorological Service
TU-Wien	Technische Universität Wien (in Austria)
U-MARF	Unified Meteorological Archive and Retrieval Facility
UniFe	University of Ferrara (in Italy)
URD	User Requirements Document
UTC	Universal Coordinated Time
VIS	Visible
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)